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(54) **STRESS-RELIEVED WIRE SEAL ASSEMBLY FOR GAS TURBINE ENGINES**

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CPC ***F01D 25/00*** (2013.01); ***F01D 5/303*** (2013.01); ***F01D 11/006*** (2013.01); *Y10T 29/49297* (2015.01)

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See application file for complete search history.

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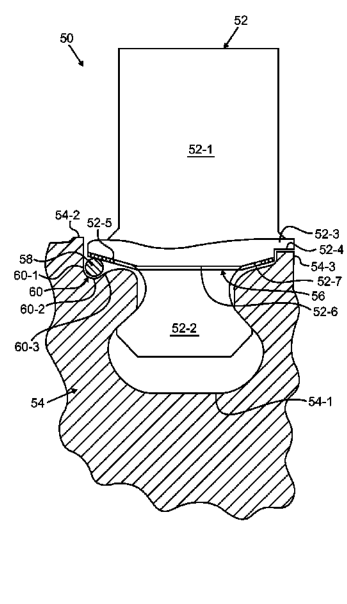
(57) **ABSTRACT**

A sealing assembly for use in a gas turbine engine having a disk arranged relative to an axis, the assembly including a circumferential groove defined in the disk and an annular wire seal positioned at least partially within the groove. The groove includes a first sidewall, a base portion adjoining the first sidewall, and a second sidewall adjoining the base portion opposite the first sidewall, wherein the second sidewall is angled in a range greater than 0° and less than 90° with respect to the axis.

18 Claims, 3 Drawing Sheets



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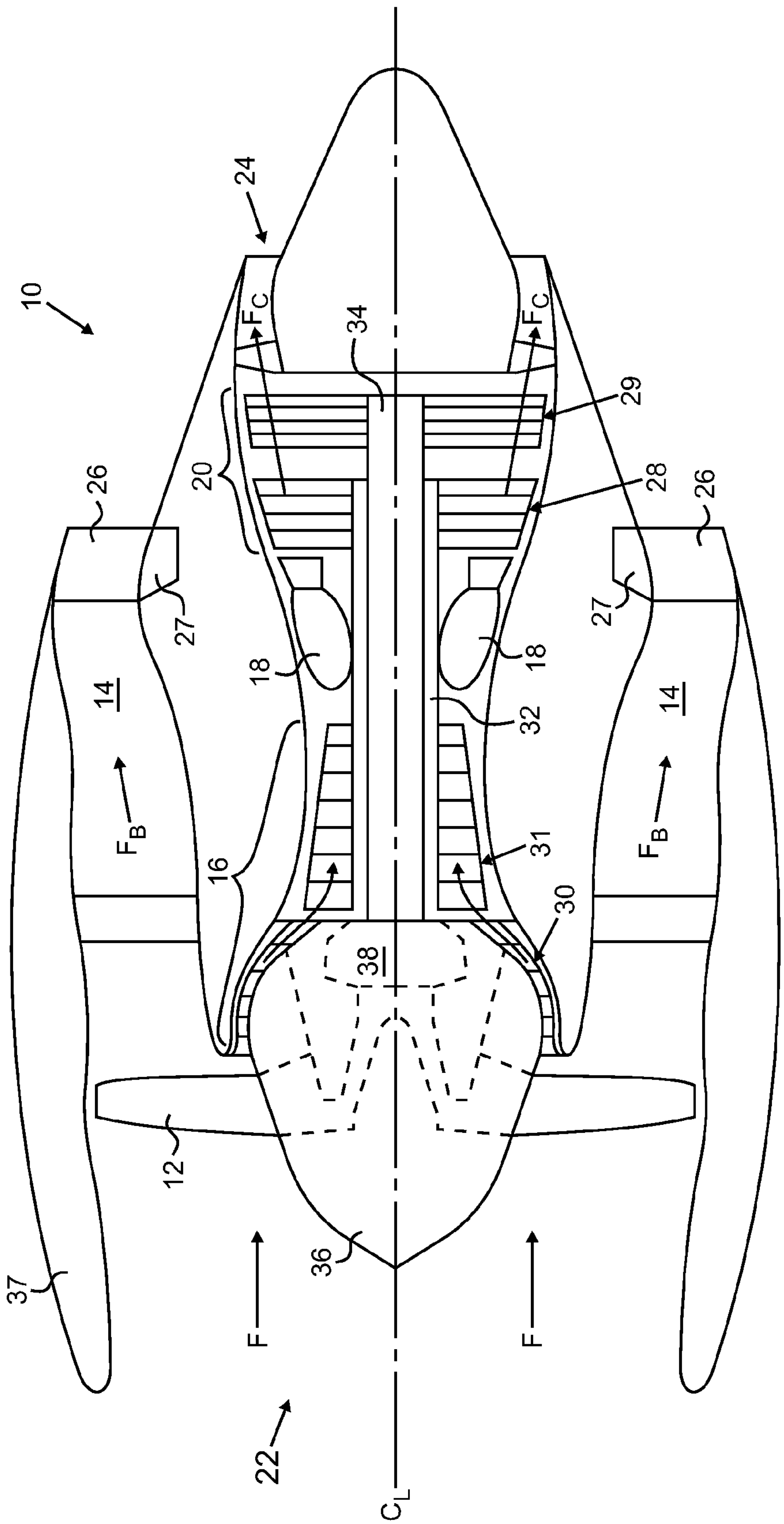
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FIG. 1

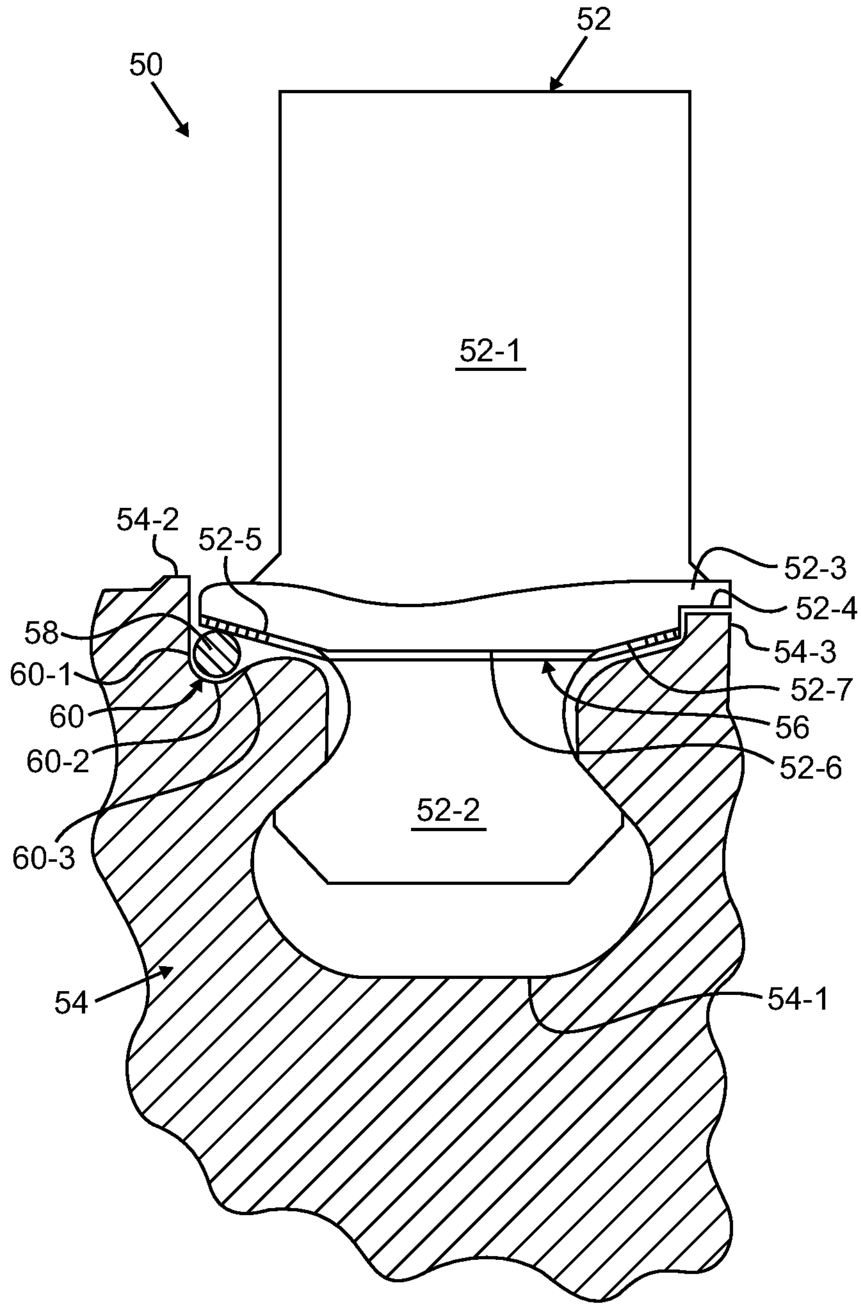
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FIG. 2

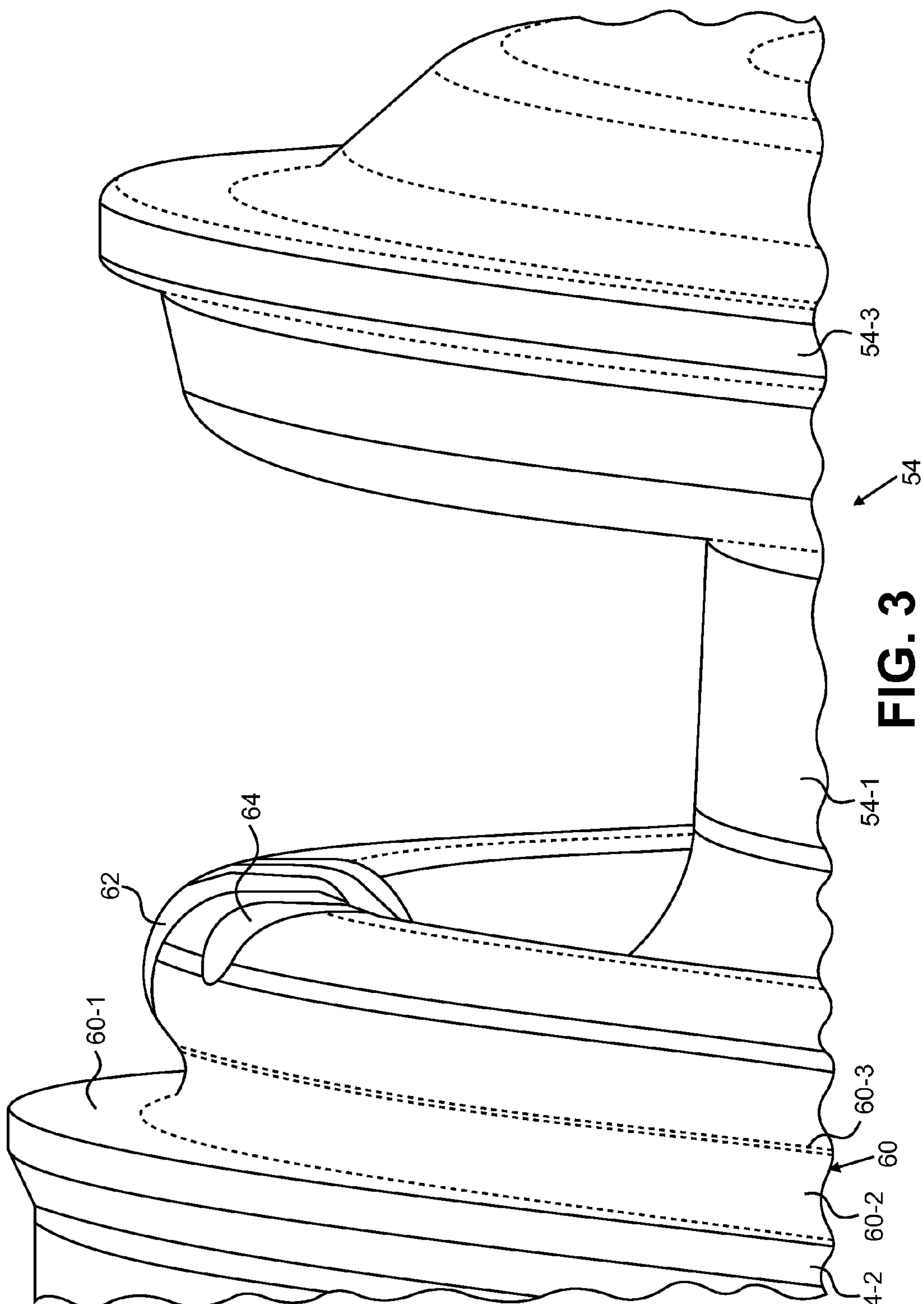

FIG. 3

STRESS-RELIEVED WIRE SEAL ASSEMBLY FOR GAS TURBINE ENGINES

BACKGROUND

The present invention relates to seals and more particularly to seals for use with gas turbine engines.

Gas turbine engines include airfoils, such as blades and vanes, arranged in cascade configurations. These airfoils can be arranged in compressor or turbine sections of the engine. The airfoils can include a root (e.g., dovetail shaped root) that allows retention of the airfoil in a mounting structure, such as a rotor disk having one or more blade retention slots. For instance, a single circumferential rotor disk slot or a plurality of generally axial slots can be provided for airfoil retention. Many such airfoils include platforms that define a portion of an endwall or flowpath boundary adjacent to a working portion of the airfoil. However, gaps or spaces remain between airfoil platforms and the mounting structure, which is generally a necessity to enable assembly of the airfoils to the mounting structure. Fluid (e.g., air) leakage can include the escape of fluid from a primary flowpath, leading to undesirable pressure loss. Wire seals positioned between compressor rotor disks and blade platforms are known as a mechanism to provide under-platform sealing. These wire seals help reduce leakage of fluid between in a generally forward-aft or axial direction.

It is desired to provide an improved wire seal assembly.

SUMMARY

A sealing assembly for use in a gas turbine engine having a disk arranged relative to an axis, the assembly including a circumferential groove defined in the disk and an annular wire seal positioned at least partially within the groove. The groove includes a first sidewall, a base portion adjoining the first sidewall, and a second sidewall adjoining the base portion opposite the first sidewall, wherein the second sidewall is angled in a range greater than 0° and less than 90° with respect to the axis.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic cross-sectional view of a gas turbine engine.

FIG. **2** is a cross-sectional view of a rotor disk assembly with a wire seal assembly according to the present invention.

FIG. **3** is a perspective view of the rotor disk of FIG. **2**, shown in isolation, with dashed lines shown to help illustrate curved surfaces.

While the above-identified drawing figures set forth at least one embodiment of the invention, other embodiments are also contemplated, as noted in the discussion. In all cases, this disclosure presents the invention by way of representation and not limitation. It should be understood that numerous other modifications and embodiments can be devised by those skilled in the art, which fall within the scope and spirit of the principles of the invention. The figures may not be drawn to scale, and applications and embodiments of the present invention may include features and components not specifically shown in the drawings.

DETAILED DESCRIPTION

In general, the present invention provides a new configuration and geometry for a wire seal groove for a disk or other structure of a gas turbine engine. Prior art wire seal grooves had purely radially-oriented U-shapes (i.e., having a rounded base with radially-oriented planar sidewalls). A wire seal groove according to the present invention can still open in a radially outward direction but can now further include an angled or skewed sidewall at least at a downstream (i.e., aft) side, which essentially eliminates material of the disk at the angled or skewed sidewall of the groove that would have been present in prior art designs. An upstream boundary of the wire seal groove can be vertically oriented (e.g., at approximately 90° with respect to an engine centerline axis), while a downstream boundary can generally be angled (e.g., at <90° with respect to the engine centerline axis) with a gently curving transition to the adjacent surface. The resultant groove still provides a volume to accept a split ring wire seal (which can expand radially outward beyond the groove), while simultaneously retaining the wire seal to reduce a risk of migration during operation. The angled portion can help provide stress-relief, such as to reduce hoop stress or other stress modes. The wire seal groove can be located on an upstream (forward) rim of the rotor disk, but could be positioned elsewhere in alternative embodiments. Furthermore, in embodiments in which the disk has a load slot for loading airfoil roots into a circumferential retention slot, the wire seal groove can be positioned to avoid intersection with the load slot.

FIG. **1** is a schematic cross-sectional view of an embodiment of a gas turbine engine **10**. The illustrated embodiment of the engine **10** shows a turbofan configuration, though persons of ordinary skill in the art will appreciate that other configurations are possible in further embodiments. The gas turbine engine **10** includes a fan section **12**, a bypass duct **14**, a turbine core that includes a compressor section **16**, a combustor section **18** and a turbine section **20**, which are arranged between an upstream inlet **22** and a downstream exhaust outlet **24**. An airflow F can enter the engine **10** via inlet **22** and can be divided into a bypass flow F_B and a core flow F_C. The bypass flow F_B can pass through the bypass duct **14**, generating thrust, and the core flow F_C passes along a primary flowpath through the compressor section **16**, the combustor section **18** and the turbine section **20**.

A variable area nozzle **26** can be positioned in bypass duct **14** in order to regulate a bypass flow F_B with respect to a core flow F_C, in response to adjustment by one or more actuators **27**. Adjustment of the variable area nozzle **26** allows the turbofan **10** to control or limit a temperature of the core flow F_C, including during times of peak thrust demand.

The turbine section **20** can include a high-pressure turbine (HPT) section **28** and a low-pressure turbine (LPT) section **29**. The compressor section **16** can include a low pressure compressor (LPC) or boost section **30** and a high pressure compressor (HPC) section **31**. The compressor **16** and turbine **20** sections can each include a number of stages of airfoils, which can be arranged as alternating cascades of rotating blades and non-rotating vanes (or stators). The HPT section **28** is coupled to the HPC **31** via a HPT shaft **32**, forming a high pressure spool. The LPT section **29** is coupled to the fan section **12** and the LPC **30** via a LPT shaft **34**, forming the low pressure or fan spool. The LPT shaft **34** can be coaxially mounted within HPT shaft **32**, about centerline axis C_L, such that the HPT and LPT spools can rotate independently (i.e., at different speeds).

The fan section **12** is typically mounted to a fan disk or other rotating member, which is driven by the LPT shaft **34**. A spinner **36** can be included covering the fan disk to improve aerodynamic performance. As shown in FIG. **1**, for example, the fan section **12** is forward-mounted in an engine cowling **37**, upstream of the bypass duct **14**. In alternative embodiments, the fan section **12** can be aft-mounted in a downstream location, with an alternative coupling configuration. Further, while FIG. **1** illustrates a particular two-spool high-bypass turbofan embodiment of turbine engine **10**, this example is provided merely by way of example and not limitation. In other embodiments, the gas turbine engine **10** can be configured either as a low-bypass turbofan or a high-bypass turbofan, in a reverse-flow configuration, the number of spools can vary, etc.

In the particular embodiment of FIG. **1**, the fan section **12** is coupled to the LPT shaft **34** via an optional planetary gear or other fan drive geared mechanism **38** (shown in dashed lines), which provides independent speed control. More specifically, the fan drive gear mechanism **38** allows the engine **10** to control the rotational speed of the fan section **12** independently of the high and low spool speeds (that is, independently of HPT shaft **32** and LPT shaft **34**), increasing the operational control range for improved engine response and efficiency across an operational envelope.

In operation, compressor **16** compresses incoming air of the core flow F_C for the combustor section **18**, where at least a portion of that air is mixed with fuel and ignited to produce hot combustion gas. The combustion gas can exit the combustor section **18** and enter the HPT section **28**, which drives the HPT shaft **32** and in turn drives the HPC **31**. Partially expanded combustion gas transitions from the HPT section **28** to the LPT section **29**, driving the fan section **12** and the LPC **30** via the LPT shaft **34** and, in some embodiments, the fan drive gear mechanism **38**. Exhaust gas can exit the engine **10** via exhaust outlet **24**.

FIG. **2** is a cross-sectional view of a rotor disk assembly **50** that includes airfoils **52** (e.g., rotor blades), a disk **54** (e.g., rotor disk), an optional ladder seal system **56**, and a wire seal **58**. FIG. **3** is a perspective view of the disk **54**, shown in isolation. The rotor disk assembly **50** can be a stage of the high pressure compressor **31**, or can be in another section of the engine **10** in further embodiments. It should be noted that in FIG. **2** only one airfoil **52** is visible.

As shown in the illustrated embodiment, each airfoil **52** can include a working portion **52-1**, a root **52-2** and a platform **52-3** located between the working portion **52-1** and the root **52-2** (as used herein, the term "root" can also encompass what is sometimes separately referred to as a "shank"). The working portion **52-1** can be positioned to extend into a primary flowpath of the engine **10** to interact with a working fluid (i.e., core flow F_C). The root **52-2** can have a dovetail shape or other desired shape to retain the airfoil **52** relative to the disk **54**. The platform **52-3** can form a portion of a boundary of the primary flowpath.

At an underside (i.e., radially inner surface, as shown in the illustrated embodiment) of the platform **52-3**, a notch **52-4**, an upstream angled portion **52-5**, a central portion **52-6**, and a downstream angled portion **52-7** can be provided.

The disk **54** includes at least one retention slot **54-1**, which in the illustrated embodiment is a single circumferentially-extending slot at an outer rim of the disk **54**. The slot **54-1** and the root **52-2** can have complementary shapes, allowing the slot **54-1** to radially retain the airfoil **52**. As explained further below, a load feature (see FIG. **3**) can be formed in the slot **54-1**, or other suitable features provided, to facilitate insertion of the root **52-2** into the slot **54-1**. Furthermore, a lock feature (see FIG. **3**) can be provided in the slot **54-1** to allow engagement of an airfoil lock (not shown) to help secure a cascade of the airfoils **52** in the slot **54-1**.

The disk **54** can further include a ramped circumferential ridge **54-2** that extends radially outward from the outer rim on an upstream side of the slot **54-1** (i.e., on an upstream rail). The ridge **54-2** can protrude radially outward at least as far as a flowpath surface (e.g., radially outward surface) of the platform **52-3** of the airfoil **52**, and be positioned upstream of a leading edge of the platform **52-3**, in order to help reduce flow separation at or near the leading edge of the platform **52-3**.

In addition, the disk **54** can further include a circumferentially-extending ridge **54-3** that extends radially outward from the outer rim on a downstream side of the slot **54-1** (i.e., on a downstream rail). The ridge **54-3** can be positioned generally upstream of a trailing edge of the platform **52-3** of the airfoil **52**, that is, with a downstream edge of the ridge **54-3** located at or upstream of the trailing edge of the platform **52-3**, such that the ridge **54-3** is positioned generally underneath the platform **54-3**. The notch **52-4** can be formed in the platform **52-3** immediately upstream of the trailing edge and can have a shape that is complementary to a shape of the ridge **54-3** of the disk **54**, with the ridge **54-3** extending into (i.e., radially overlapping with) the notch **52-4**. A sealing effect is provided by the notch **52-4** and the ridge **54-3**, which together alter the shape of a space between the platform **52-3** and the disk **54**. In alternative embodiments, the notch **52-4** and the ridge **54-3** could instead be located at or near a leading edge of the platform **52-3** and an upstream rail of the disk **54**, respectively.

The wire seal **58** can be a full hoop (i.e., 360°) split ring, and can be made of a suitable metallic material. In the illustrated embodiment the wire seal **58** has a substantially circular cross-sectional shape. The wire seal **58** is positioned at least partially within a wire seal groove **60** located on the outer rim of the disk **54** that opens radially outwardly to accept the wire seal **58**. During operation of the engine **10**, the wire seal can expand radially outwardly and rest against the platforms **52-3** of the airfoils **52** (e.g., against the upstream angled portion **52-5**) or against the ladder seal system **56**, if present. The wire seal can generally provide sealing in an upstream-downstream or axial direction (relative to the centerline axis C_L). In the illustrated embodiment, the wire seal **58** and the wire seal groove **60** are both positioned at an upstream rim of the risk **54**, that is, upstream or forward of the slot **54-1**. In further embodiments, one or more additional wire seals **58** and wire seal grooves **60** can be provided such that wire seals **58** are located on both sides of the slot **54-1**. In another embodiment, the wire seal **58** and wire seal groove **60** could be positioned downstream or aft of the slot **54-1** rather than upstream of the slot **54-1**. The particular number and location of wire seals **58** and corresponding grooves **60** can vary as desired for particular applications.

The wire seal groove **60** can include an upstream sidewall **60-1**, a base **60-2** and a downstream sidewall **60-3**. In the illustrated embodiment, the upstream sidewall **60-1** can have a substantially planar, radially-oriented configuration (i.e., at approximately 90° with respect to the centerline axis C_L), and can adjoin and form part of a trailing edge of the ramped circumferential ridge **54-2**. The base **60-2** adjoins the upstream sidewall **60-1** can have a radially inwardly radiused configuration (e.g., with a radius approximately equal to a radius of the wire seal **58**), such that no sharp corners are present between the upstream sidewall **60-1** and the base **60-2**. The downstream sidewall **60-3** adjoins the base **60-2** opposite the upstream sidewall **60-1**. In the illustrated embodiment, the downstream sidewall **60-3** has an angled or skewed configuration (i.e., at an angle greater than 0° and less than 90° with respect to the centerline axis C_L), that generally orients the downstream sidewall **60-3** at a different angle than the upstream sidewall **60-1**. In one embodiment, the downstream sidewall **60-3** can be angled in a range of about 0°-50°. The downstream sidewall **60-3** angles away from the base

60-2 in the illustrated embodiment, which essentially eliminates material of the disk 54 and widens and enlarges an open volume of the wire seal groove 60. The particular angle of the downstream sidewall 60-3 can be selected such that wire seal 58 remains axially constrained by the groove 60, though some axially movement is permitted. Axial movement of the wire seal 58 should be limited though to help prevent binding or the formation of leakage paths around the wire seal 58. A smooth curvature can be provided along the downstream sidewall 60-3 such that sharp corners are avoided between the base 60-2 and the retention slot 54-1. The groove 60, including the downstream sidewall 60-3, has substantially the same shape around an entire circumference of the disk 54 in the illustrated embodiment.

As shown in FIG. 3, a load slot 62 and a lock slot 64 can be provided along the retention slot 54-1 in the disk 54. The load slot 62 can facilitate insertion of the roots 52-2 of the airfoils 52 into the retention slot 54-1 of the disk 54. The lock slot 64 can be locate adjacent to the load slot 62, and can provide space for a locking mechanism (e.g., blade lock) that helps retain the airfoils 52 in the retention slot 54-1. Examples of load slots and lock slots are disclosed in commonly-assigned U.S. Pat. App. Pub. No. 2001/0116933. Additional slots extending from the retention slot 54-1 can also be provided as desired for particular applications.

The inventors have discovered that intersection of the wire seal groove 60 and the load slot 62, lock slot 64 or other slot feature can cause undesirable stress concentration. Accordingly, in one embodiment, the wire seal groove 60 can be positioned forward of (i.e., spaced upstream from) the load slot 62 and the lock slot 64 to avoid intersection. Furthermore, the downstream sidewall 60-3 of the wire seal groove 60 can be configured to avoid a leakage path through the load slot 62 due to migration of the wire seal 58 during operation of the engine 10.

Any relative terms or terms of degree used herein, such as "substantially", "essentially", "generally" and the like, should be interpreted in accordance with and subject to any applicable definitions or limits expressly stated herein. In all instances, any relative terms or terms of degree used herein should be interpreted to broadly encompass any relevant disclosed embodiments as well as such ranges or variations as would be understood by a person of ordinary skill in the art in view of the entirety of the present disclosure, such as to encompass ordinary manufacturing tolerance variations, incidental alignment variations, alignment or shape variations induced by thermal or rotational operational conditions, and the like.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

Discussion of Possible Embodiments

The following are non-exclusive descriptions of possible embodiments of the present invention.

A sealing assembly for use in a gas turbine engine having a disk arranged relative to an axis, the assembly including a circumferential groove defined in the disk, and an annular wire seal positioned at least partially within the groove. The groove includes a first sidewall; a base portion adjoining the first sidewall; and a second sidewall adjoining the base portion opposite the first sidewall, wherein the second sidewall is angled in a range greater than 0° and less than 90° with respect to the axis.

The assembly of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:

- the first sidewall can be angled at approximately 90° with respect to the axis;
- the first sidewall can be substantially planar;
- a ramped circumferential ridge that extends radially outward from the disk, wherein the first sidewall adjoins and forms a part of an edge of the ramped circumferential ridge;
- an airfoil retention slot defined in the disk, wherein the circumferential groove is located upstream of the airfoil retention slot;
- a smooth curvature can be provided between the base portion and the airfoil retention slot, including along the second sidewall;
- an airfoil retained by the disk, the airfoil having a platform and a notch at an edge of the platform; and a circumferential ridge extending radially outward from the disk and at least partially into the notch;
- the wire seal can comprise a full hoop split ring having a substantially circular cross-sectional shape; and/or
- a radius of the base portion of the groove can be approximately equal to a cross-sectional radius of the split ring wire seal.

A method of making a sealing assembly for a gas turbine engine includes creating a circumferential groove adjacent in a structure to an airfoil retention slot, wherein the groove is created with a first sidewall, a base portion adjoining the first sidewall, a second sidewall adjoining the base portion opposite the first sidewall, and wherein the second sidewall is angled in a range greater than 0° and less than 90° with respect to an engine axis; and positioning an annular wire seal at least partially within the groove.

The method of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features and/or additional steps:

- creating a ramped circumferential ridge that extends radially outward from the structure, such that the first sidewall adjoins and forms a part of an edge of the ramped circumferential ridge; and/or
- creating a notch at an edge of a platform of an airfoil; creating a circumferential ridge extending radially outward from the structure adjacent to the airfoil retention slot; and inserting the airfoil into the airfoil retention slot such that the circumferential ridge at least partially extends into the notch.

A sealing assembly for use in a gas turbine engine includes a retention structure arranged relative to an engine axis; an airfoil retention slot defined in the retention structure; an airfoil retained by the airfoil retention slot; a circumferential groove defined in the retention structure adjacent to the airfoil retention slot, and an annular wire seal positioned at least partially within the groove. The groove includes a first sidewall; a base portion adjoining the first sidewall; and a second sidewall adjoining the base portion opposite the first sidewall, wherein the second sidewall is angled in a range greater than 0° and less than 90° with respect to the axis.

The assembly of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:

the first sidewall can be angled at approximately 90° with respect to the axis;

the first sidewall can be substantially planar;

a ramped circumferential ridge that extends radially from the retention structure, wherein the first sidewall adjoins and forms a part of an edge of the ramped circumferential ridge;

the groove can be located upstream of the airfoil retention slot;

a smooth curvature can be provided between the base portion and the airfoil retention slot, including along the second sidewall;

the airfoil can further include a platform and a notch at an edge of the platform, and the retention structure can further include a circumferential ridge extending radially and at least partially into the notch; and/or

the wire seal can comprise a full hoop split ring having a substantially circular cross-sectional shape, and a radius of the base portion of the groove can be approximately equal to a cross-sectional radius of the split ring wire seal.

The invention claimed is:

1. A sealing assembly for use in a gas turbine engine having a disk arranged relative to an axis of rotation of the gas turbine engine, the assembly comprising:

a circumferential groove defined in the disk, the groove including:

a first sidewall;

a base portion adjoining the first sidewall; and

a second sidewall adjoining the base portion opposite the first sidewall, wherein the second sidewall adjoins the base portion at a location where a concave curvature of the base portion terminates, wherein the second sidewall includes a smooth convex curve, and wherein the entire second sidewall is angled away from the base portion such that the second sidewall is angled in a range greater than 0° and less than 90° with respect to the axis; and

an annular wire seal positioned at least partially within the groove.

2. The assembly of claim **1**, wherein the first sidewall is angled at approximately 90° with respect to the axis.

3. The assembly of claim **2**, wherein the first sidewall is substantially planar.

4. The assembly of claim **1** and further comprising:

a ramped circumferential ridge that extends radially outward from the disk, wherein the first sidewall adjoins and forms a part of an edge of the ramped circumferential ridge.

5. The assembly of claim **1** and further comprising:

an airfoil retention slot defined in the disk, wherein the circumferential groove is located upstream of the airfoil retention slot.

6. The assembly of claim **1** and further comprising:

an airfoil retained by the disk, the airfoil having a platform and a notch at an edge of the platform; and

a circumferential ridge extending radially outward from the disk and at least partially into the notch.

7. The assembly of claim **1**, wherein the wire seal comprises a full hoop split ring having a substantially circular cross-sectional shape.

8. The assembly of claim **7**, wherein a radius of the base portion of the groove is approximately equal to a cross-sectional radius of the split ring wire seal.

9. A method of making a sealing assembly for a gas turbine engine, the method comprising:

creating a circumferential groove adjacent in a structure to an airfoil retention slot, wherein the groove is created with a first sidewall, a base portion adjoining the first sidewall, a second sidewall adjoining the base portion opposite the first sidewall, wherein the second sidewall adjoins the base portion at a location where a concave curvature of the base portion terminates, wherein the second sidewall includes a smooth convex curve, and wherein the entire second sidewall is angled away from the base portion such that the second sidewall is angled in a range greater than 0° and less than 90° with respect to an engine axis of rotation; and

positioning an annular wire seal at least partially within the groove.

10. The method of claim **9** and further comprising:

creating a ramped circumferential ridge that extends radially outward from the structure, such that the first sidewall adjoins and forms a part of an edge of the ramped circumferential ridge.

11. The method of claim **9** and further comprising:

creating a notch at an edge of a platform of an airfoil;

creating a circumferential ridge extending radially outward from the structure adjacent to the airfoil retention slot; and

inserting the airfoil into the airfoil retention slot such that the circumferential ridge at least partially extends into the notch.

12. A sealing assembly for use in a gas turbine engine, the assembly comprising:

a retention structure arranged relative to an axis of rotation of the gas turbine engine;

an airfoil retention slot defined in the retention structure;

an airfoil retained by the airfoil retention slot;

a circumferential groove defined in the retention structure adjacent to the airfoil retention slot, the groove including:

a first sidewall;

a base portion adjoining the first sidewall; and

a second sidewall adjoining the base portion opposite the first sidewall, wherein the second sidewall adjoins the base portion at a location where a concave curvature of the base portion terminates, wherein the second sidewall includes a smooth convex curve, and wherein the entire second sidewall is angled away from the base portion such that the second sidewall is angled in a range greater than 0° and less than 90° with respect to the axis; and

an annular wire seal positioned at least partially within the groove.

13. The assembly of claim **12**, wherein the first sidewall is angled at approximately 90° with respect to the axis.

14. The assembly of claim **13**, wherein the first sidewall is substantially planar.

15. The assembly of claim **12** and further comprising:

a ramped circumferential ridge that extends radially from the retention structure, wherein the first sidewall adjoins and forms a part of an edge of the ramped circumferential ridge.

16. The assembly of claim **12**, wherein the groove is located upstream of the airfoil retention slot.

17. The assembly of claim **12**, wherein the airfoil further includes a platform and a notch at an edge of the platform, and wherein the retention structure further includes a circumferential ridge extending radially and at least partially into the notch.

18. The assembly of claim **12**, wherein the wire seal comprises a full hoop split ring having a substantially circular cross-sectional shape, and wherein a radius of the base portion of the groove is approximately equal to a cross-sectional radius of the split ring wire seal.

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